WORLD RESOURCES INSTITUTE

Working Paper

AQUEDUCT METADATA DOCUMENT

AQUEDUCT GLOBAL MAPS 2.0

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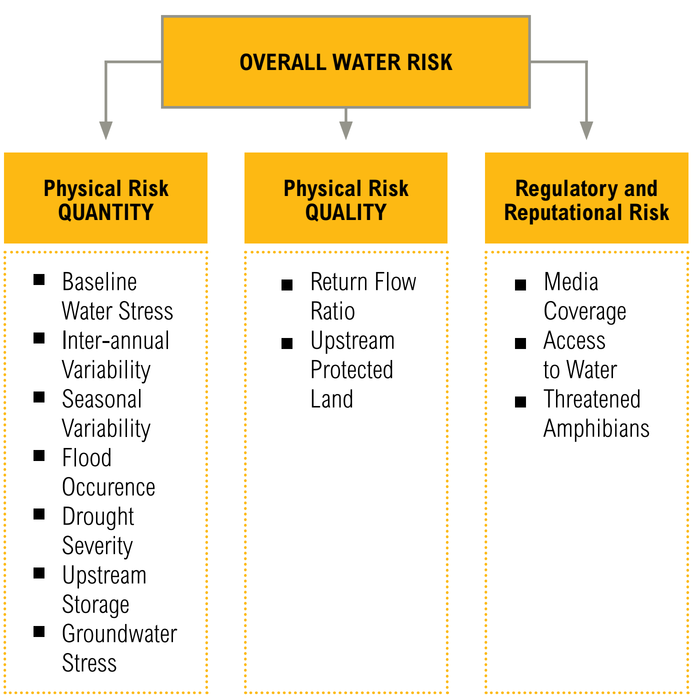
EXECUTIVE SUMMARY

This document describes the specific characteristics of the indicator data and calculations for the Aqueduct Water Risk Atlas Global Maps. Complete guidelines and processes for data collection, calculations, and mapping techniques are described fully in the Aqueduct Water Risk Framework.[1] The Aqueduct Water Risk Atlas makes use of a Water Risk Framework (Figure 1), that includes 12 global indicators grouped into three categories of risk and one overall score.

Figure 1 | **Aqueduct Water Risk Framework**



CONTENTS

Disclaimer: *Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form and their content may be revised.*

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The data selection and validation process involves three steps: (1) a literature review, (2) identification of data sources in the public domain, and (3) the compilation and expert review of the selected data sources. Calculation of 6 of the 12 indicators required the creation of original datasets to estimate water availability and use. The hydrological catchments were based on the Global Drainage Basin Database developed by Masutomi et al.[2] Computation of the original datasets was completed by ISciences, L.L.C.

Two measures of water use are required: water withdrawal, the total amount of water abstracted from freshwater sources for human use; and consumptive use, the portion of water that evaporates or is incorporated into a product, thus no longer available for downstream use. Withdrawals for the global basins are spatially disaggregated by sector based on regressions with spatial datasets to maximize the correlation with the reported withdrawals (i.e. irrigated areas for agriculture, nighttime lights for industrial, and population for domestic withdrawals). Consumptive use is derived from total withdrawals based on ratios of consumptive use to withdrawals by Shiklomanov and Rodda[3] and Flörke et al.[4] Both withdrawals and consumptive use are coded at the hydrological catchment scale.

Two metrics of water supply were computed: total blue water and available blue water. Total blue water approximates natural river discharge and does not account for withdrawals or consumptive use. Available blue water is an estimate of surface water availability minus upstream consumptive use. Modeled estimates of water supply are calculated using a catchment-to-catchment flow accumulation approach developed by ISciences, L.L.C., which aggregates water by catchment and transports it to the next downstream catchment. Water supply is computed from runoff (R), the water available to flow across the landscape from a particular location, and is calculated as the remainder of precipitation (P) after evapotranspiration (ET) and change in soil moisture storage (ΔS) are accounted for (i.e., $R = P - ET - \Delta S$). The runoff data is courtesy of NASA Goddard Earth Sciences Data and Information Services Center's Global Land Data Assimilation System Version 2 NOAH land surface model for the years 1950 to 2008.[5]

The remainder of this document contains the definitions, formulas, and data specifications for the Aqueduct Water Risk Atlas global maps.

TOTAL WITHDRAWAL

Description: *Total withdrawal* is the total amount of water removed from freshwater sources for human use.

Calculation: Withdrawals were estimated in a two-step process. First, national-level withdrawals were estimated for the year 2010 using multiple regression time-series models of withdrawals as a function of annually measured indicators such as GDP, population, irrigated area, or electrical power production. Regressions were performed separately for each sector (domestic, industrial, and agricultural) and were used to predict withdrawals for 2010, whenever FAO Aquastat values were older than 2008. Where FAO Aquastat reported withdrawals for the year 2008 or more recent, reported values were used.

Second, these withdrawal estimates were then spatially disaggregated by sector based on regressions with spatial datasets selected to maximize the correlation with the reported withdrawals (irrigated areas for agricultural, nighttime lights and power plants for industrial, and population for domestic withdrawals).

Data Sources

VARIABLE	BASIN DELINEATIONS
Authors	Y. Masutomi, Y. Inui, K. Takahashi, and Y. Matsuoka
Title	Development of Highly Accurate Global Polygonal Drainage Basin Data
Year of publication	2009
URL	http://www.cger.nies.go.jp/db/gdbd/gdbd_index_e.html
Resolution	1 sq. km

VARIABLE	FRESHWATER WITHDRAWAL BY COUNTRY
Author	P. H. Gleick
Title	The World's Water Volume 7: The Biennial Report on Freshwater Resources, Island Press
Year of publication	2011
URL	http://www.worldwater.org/data.html
Resolution	Country

Data Sources

VARIABLE	GRIDDED POPULATION
Authors	Center for International Earth Science Information Network (CIESIN), Columbia University; United Nations Food and Agriculture Organization (FAO); and Centro Internacional de Agricultura Tropical (CIAT)
Title	Gridded Population of the World Version 3 (GPWv3): Population Count Grid, Future Estimates
Year of publication	2005
Time covered in analysis	2005
URL	http://sedac.ciesin.columbia.edu/gpw
Resolution	2.5 arc minute raster

VARIABLE	NIGHTTIME LIGHTS
Author	NOAA National Geophysical Data Center (NGDC)
Title	Version 4 DMSP-OLS Nighttime Lights Time Series
Year of publication	2010
Time covered in analysis	2000
URL	http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html
Resolution	30 arc second raster

VARIABLE	GLOBAL IRRIGATION AREAS
Authors	S. Siebert, P. Döll, S. Feick, J. Hoogeveen, and K. Frenken
Title	Global Map of Irrigation Areas Version 4.0.1
Year of publication	2007
Time covered in analysis	2000
URL	http://www.fao.org/nr/water/aquastat/irrigationmap/index60.stm
Resolution	5 arc minute raster

VARIABLE	IRRIGATED AGRICULTURAL AREAS
Author	Food and Agriculture Organization of the United Nations (FAO)
Title	FAOSTAT
Year of publication	2009
Time covered in analysis	2009
URL	http://faostat3.fao.org/home/index.html
Resolution	Country

VARIABLE	AREA EQUIPPED FOR IRRIGATION
Authors	K. Freydank and S. Siebert
Title	Towards Mapping the Extent of Irrigation in the Last Century: Time Series of Irrigated Area per Country
Year of publication	2008
Time covered in analysis	1990– 2003
URL	http://publikationen.ub.uni-frankfurt.de/frontdoor/index/index/docId/5916
Resolution	Country

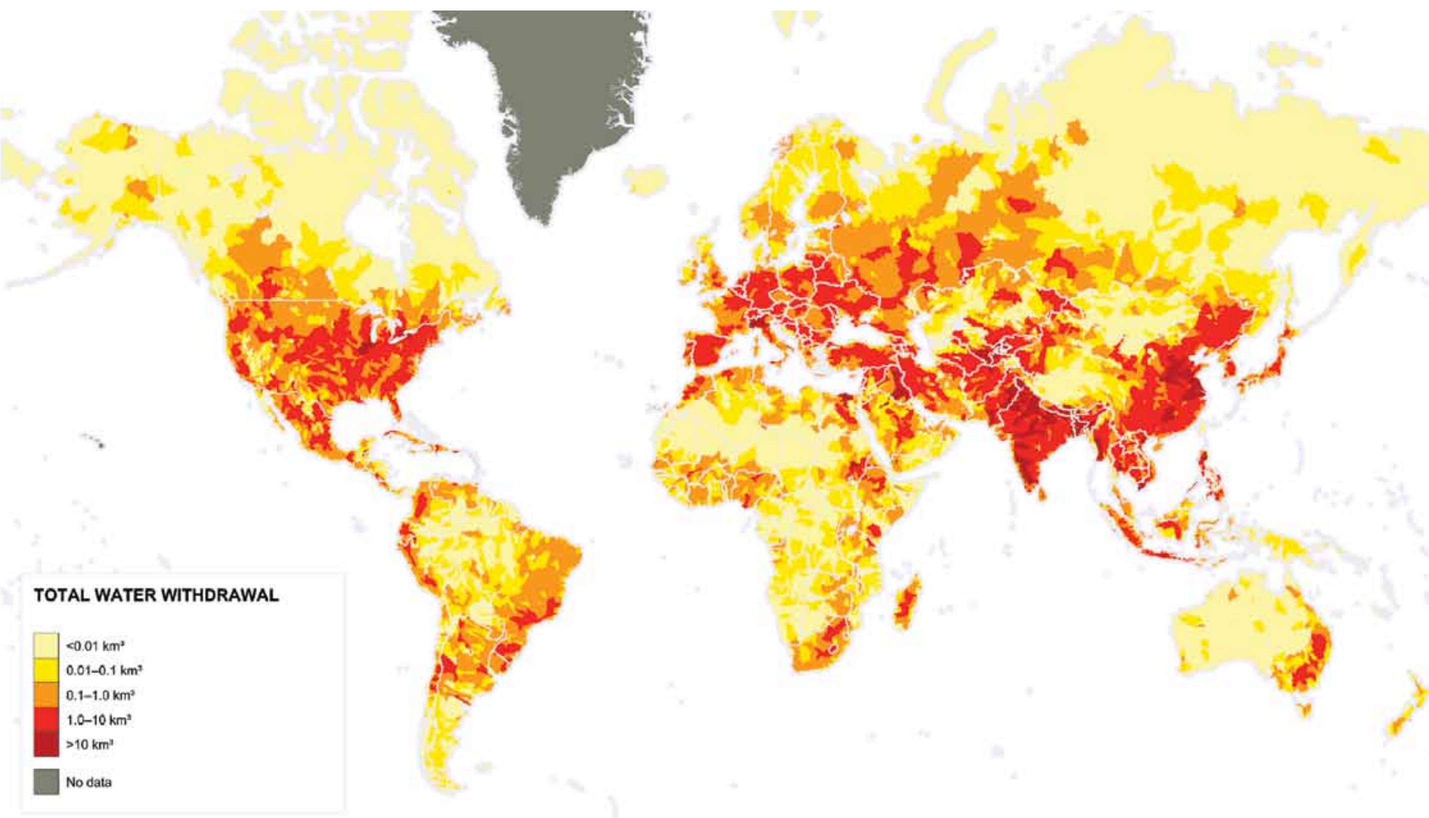
VARIABLE	GDP, POPULATION, AGRICULTURAL LAND, URBAN POPULATION, CO_2 EMISSIONS
Author	World Bank
Title	World Development Indicators
Year of publication	2011
URL	http://data.worldbank.org/data-catalog/world-development-indicators
Resolution	Country

Data Sources

VARIABLE	ELECTRICITY, TOTAL NET GENERATION, REFINERY PROCESSING GAIN, COAL PRODUCTION
Author	U.S. Energy Information Administration (EIA)
Title	International Energy Statistics
Year of publication	2011
URL	http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm
Resolution	Country

VARIABLE	WITHDRAWALS, PRECIPITATION, TOTAL RENEWABLE WATER SUPPLY, IRRIGATED AREA
Author	Food and Agriculture Organization of the United Nations (FAO)
Title	FAO AQUASTAT
URL	http://www.fao.org/nr/water/aquastat/dbase/index.stm
Date Accessed	May 24, 2012
Resolution	Country

Total Withdrawal



CONSUMPTIVE AND NON-CONSUMPTIVE USE

Description: *Consumptive use* is the portion of all water withdrawn that is consumed through evaporation, incorporation into a product, or pollution, such that it is no longer available for reuse. Non-consumptive use is the remainder of withdrawals that is not consumed and instead returns to ground or surface water bodies.

Calculation: Consumptive use by sector is estimated from total withdrawal using consumptive use ratios by Shiklomanov and Rodda and Flörke et al.

Data Sources

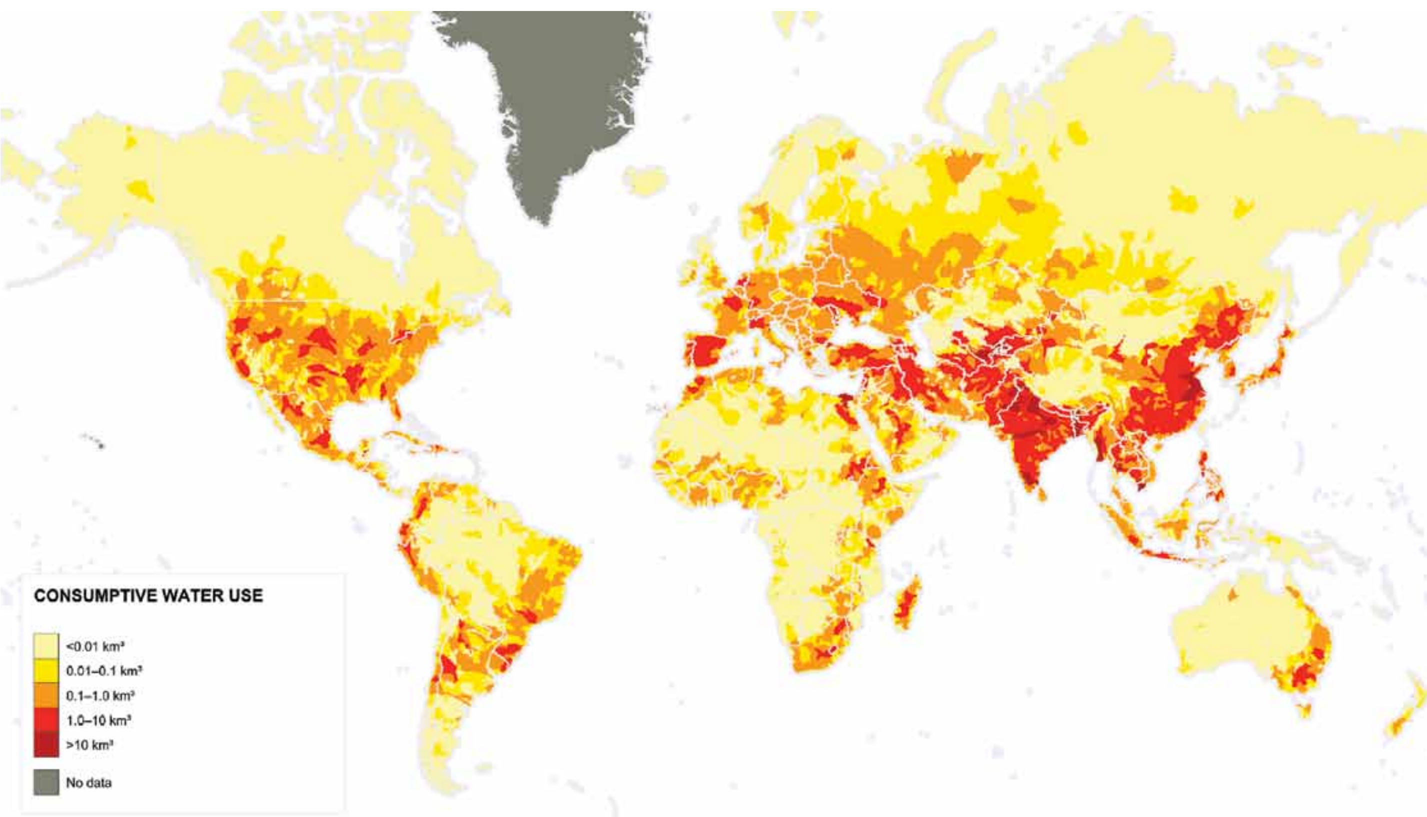
VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

Data Sources

VARIABLE	CONSUMPTIVE USE RATIOS
Authors	I.A. Shiklomanov and John C. Rodda eds.
Title	*World Water Resources at the Beginning of the Twenty-First Century,* International Hydrology Series, Cambridge University Press
Year of publication	2004
Resolution	Major regions

VARIABLE	GLOBAL WATER USE
Authors	M. Flörke, E. Kynast, I. Bärlund, S. Eisner, F. Wimmer, and J. Alcamo
Title	"Domestic and Industrial Water Uses of the Past 60 Years as a Mirror of Socio-Economic Development: A Global Simulation Study," Global Environmental Change in press, 2012.
Year of publication	2012
Resolution	Country

Consumptive and Non-Consumptive Use



TOTAL BLUE WATER (Bt)

Description: *Total blue water (Bt)* for each catchment is the accumulated runoff upstream of the catchment plus the runoff in the catchment.

Calculation: Bt(i) = Rup(i) + R(i) where Rup(i) = ∑ Bt(iup), iup is the set of catchments immediately upstream of catchment i that flow into catchment i, and Rup(i) is the summed runoff in all upstream catchments. For first-order catchments (those without upstream catchments, e.g., headwater catchments), Rup(i) is zero, and total blue water is simply the volume of runoff in the catchment.

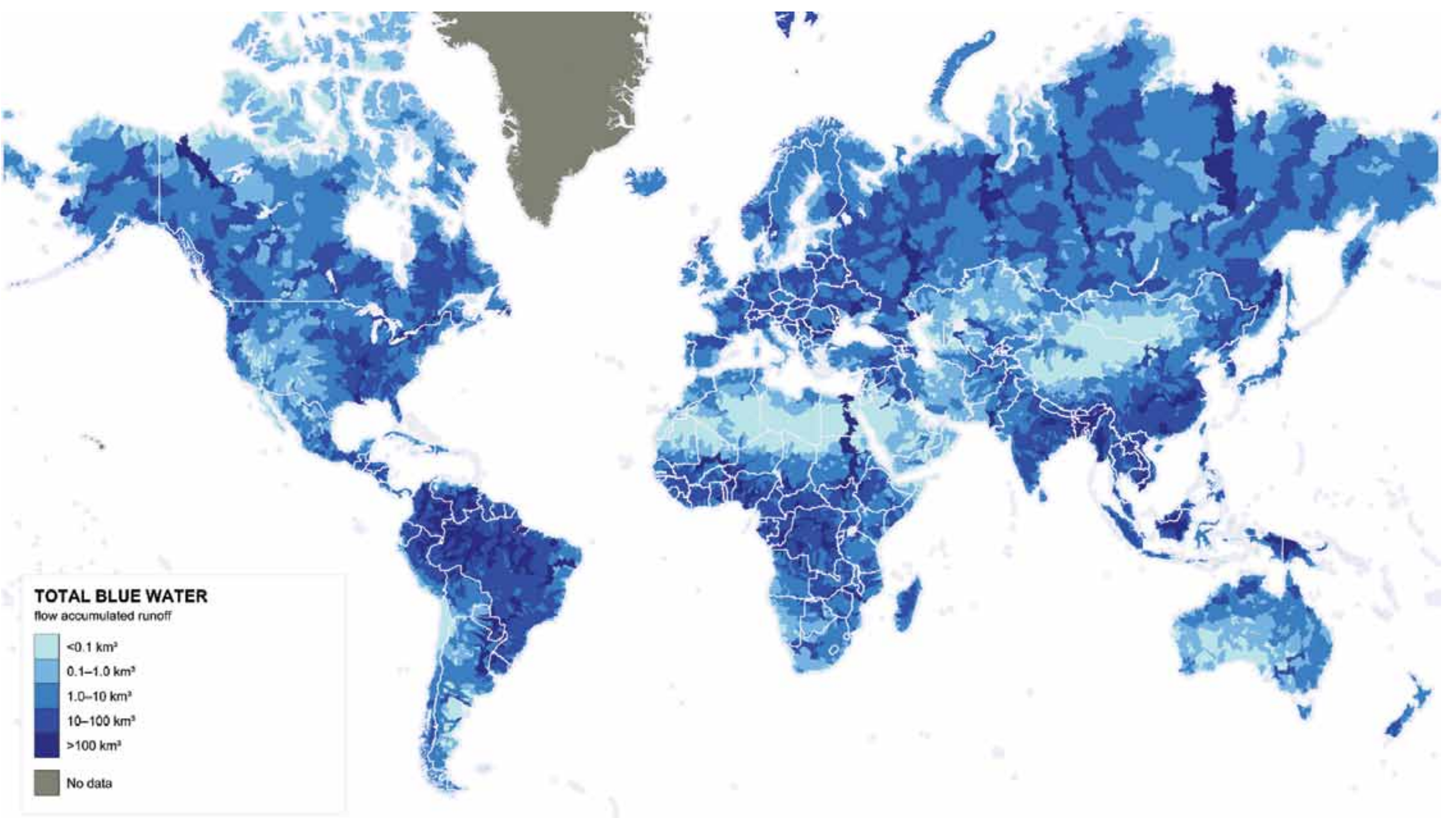
Data Sources

VARIABLE	BASIN DELINEATIONS
Comments	See Total Withdrawal

Data Sources

VARIABLE	RUNOFF
Author	National Aeronautics and Space Administration (NASA)
Title	Global Land Data Assimilation System Version 2 (GLDAS-2)
Year of publication	2012
Time covered in analysis	1950–2008
URL	http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings
Resolution	1 degree raster

Total Blue Water



AVAILABLE BLUE WATER (Ba)

Description: *Available blue water (Ba)* is the total amount of water available to a catchment before any uses are satisfied. It is calculated as all water flowing into the catchment from upstream catchments plus any imports of water to the catchment (Eim(i)) minus upstream consumptive use plus runoff in the catchment.

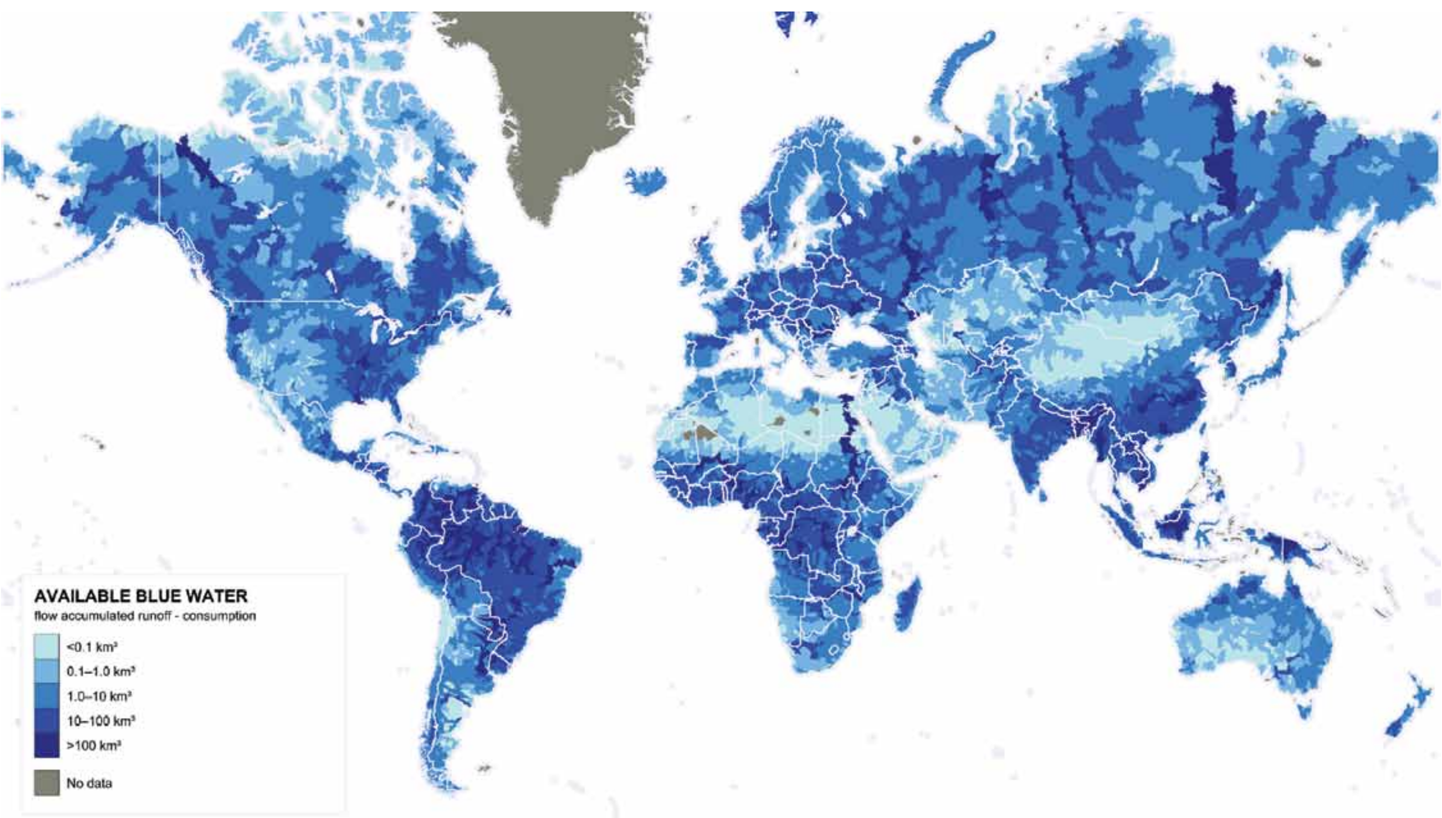
Calculation: $Ba(i) = R(i) + Eim(i) + \sum Qout(iup)$ where Qout is defined as the volume of water exiting a catchment to its downstream neighbor: $Qout(i) = \max(0, Ba(i) - Uc(i) - L(i) - Ex(i))$, Uc(i) are the consumptive uses, L(i) are the in-stream losses due to reservoirs and other infrastructure, and Ex(i) are the exports of water from catchment i. Negative values of Qout are set to zero. In first-order catchments $\sum Qout(j)$ is zero, so available blue water is runoff plus imports.

Data Sources

VARIABLE	RUNOFF
Comments	See Total Blue Water

VARIABLE	CONSUMPTIVE USE
Comments	See Consumptive and Non-consumptive Use

Available Blue Water



BASELINE WATER STRESS

Description: *Baseline water stress* measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow. Higher values indicate more competition among users. Arid areas with low water use are shown in gray, but scored as high stress when calculating aggregated scores.

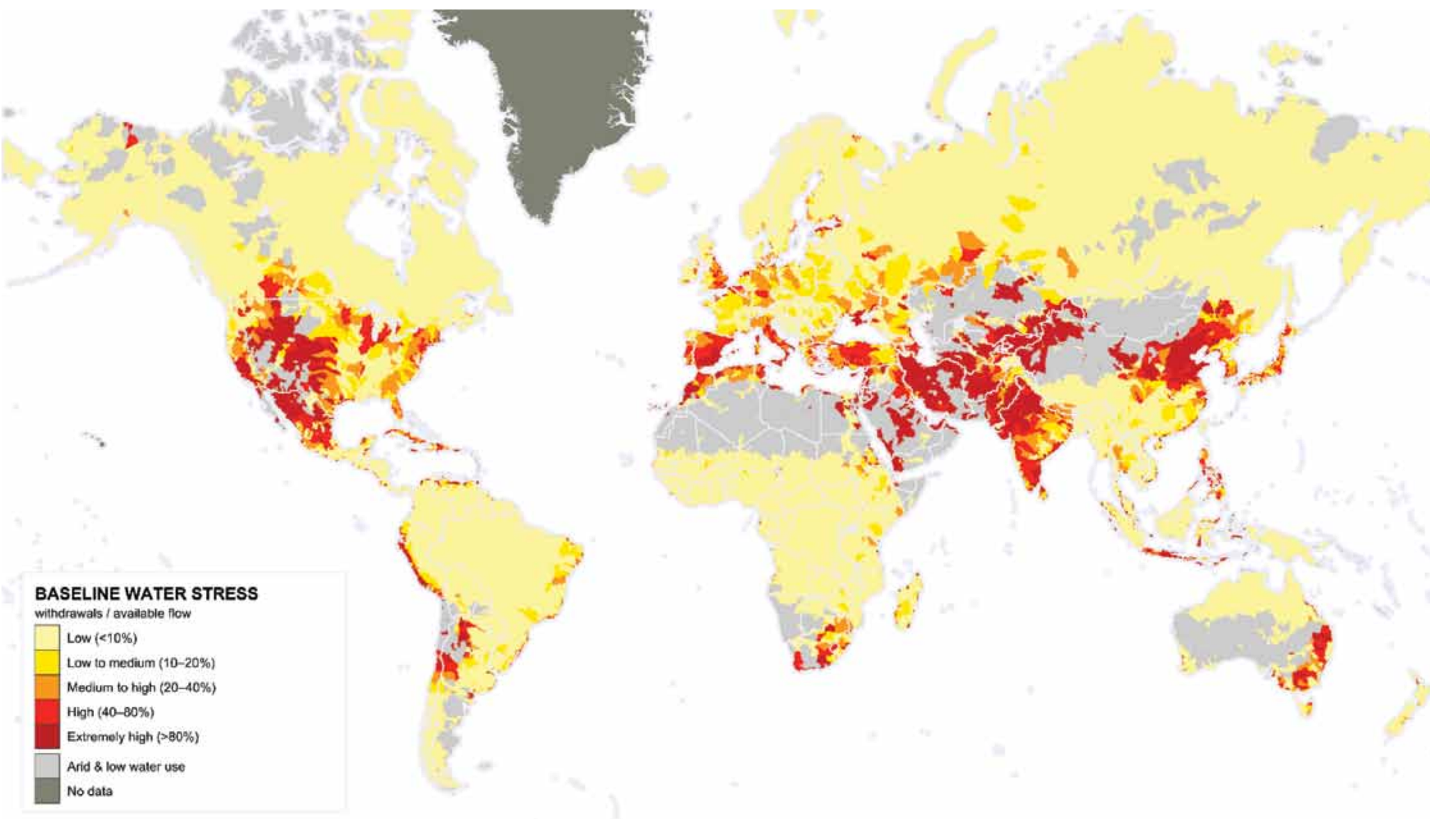
Calculation: Water withdrawals (2010) divided by mean available blue water (1950–2008). Areas with available blue water and water withdrawal less than 0.03 and 0.012 m/m^2 respectively are coded as "arid and low water use".

Data Sources

VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

VARIABLE	AVAILABLE BLUE WATER
Comments	See Available Blue Water

Baseline Water Stress



INTER-ANNUAL VARIABILITY

Description: *Inter-annual variability* measures the variation in water supply between years.

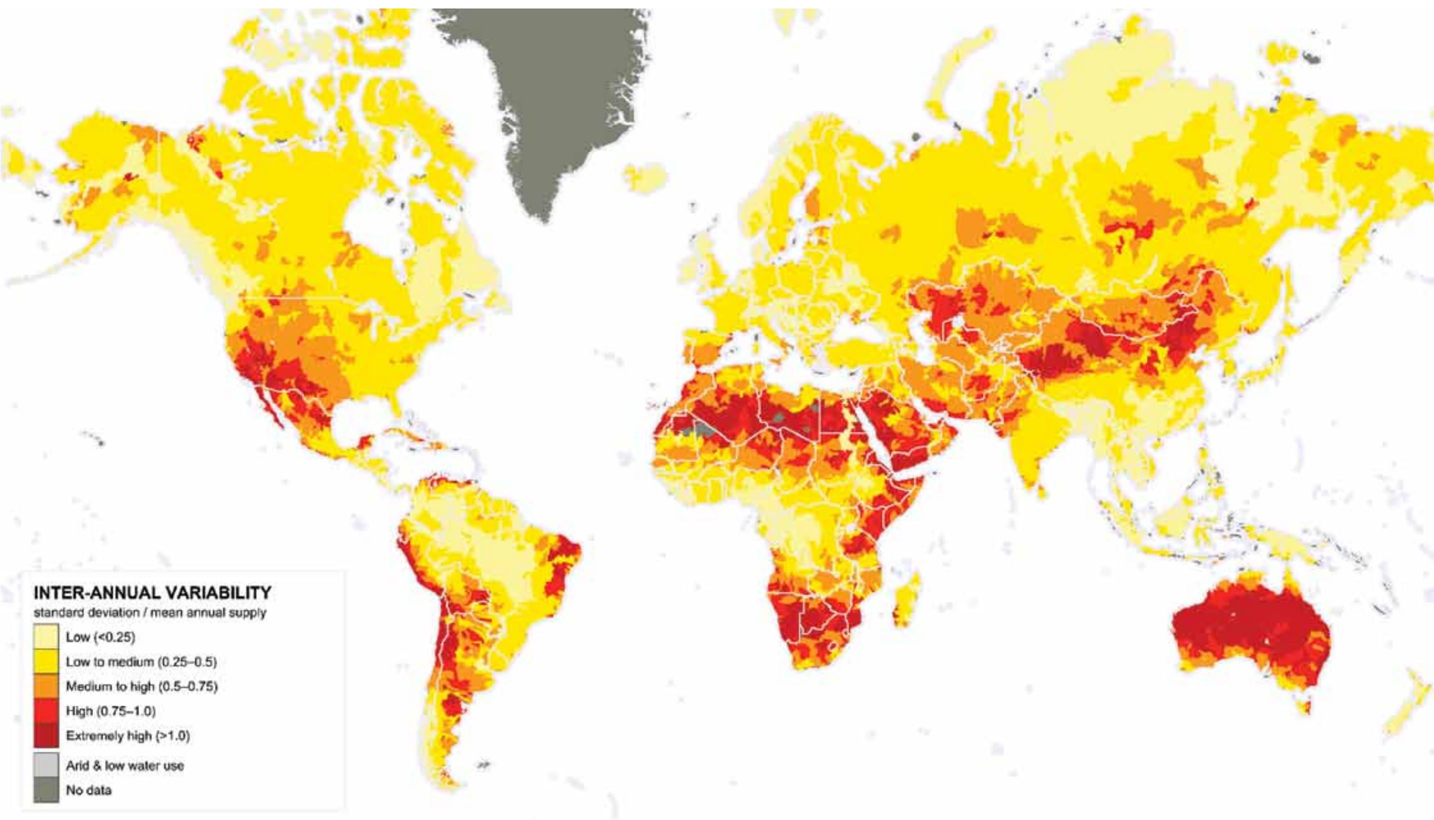
Calculation: Standard deviation of annual total blue water divided by the mean of total blue water (1950–2008).

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

VARIABLE	CONSUMPTIVE USE
Comments	See Consumptive and Non-consumptive Use

Inter-annual Variability



SEASONAL VARIABILITY

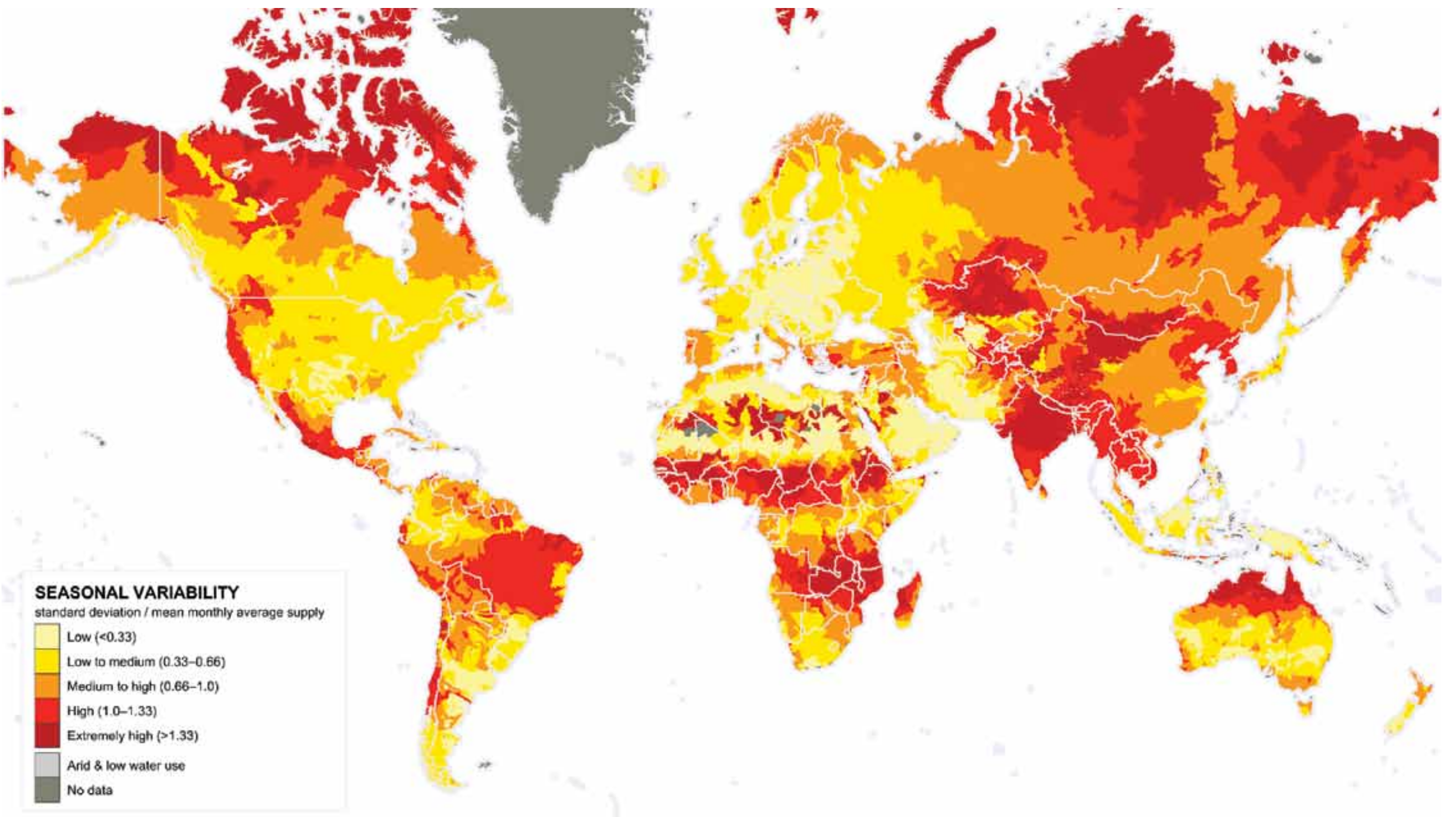
Description: *Seasonal variability* measures variation in water supply between months of the year.

Calculation: Standard deviation of monthly total blue water divided by the mean of monthly total blue water (1950–2008). The means of total blue water for each of the 12 months of the year were calculated, and the variances estimated between the mean monthly values.

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Seasonal Variability



FLOOD OCCURRENCE

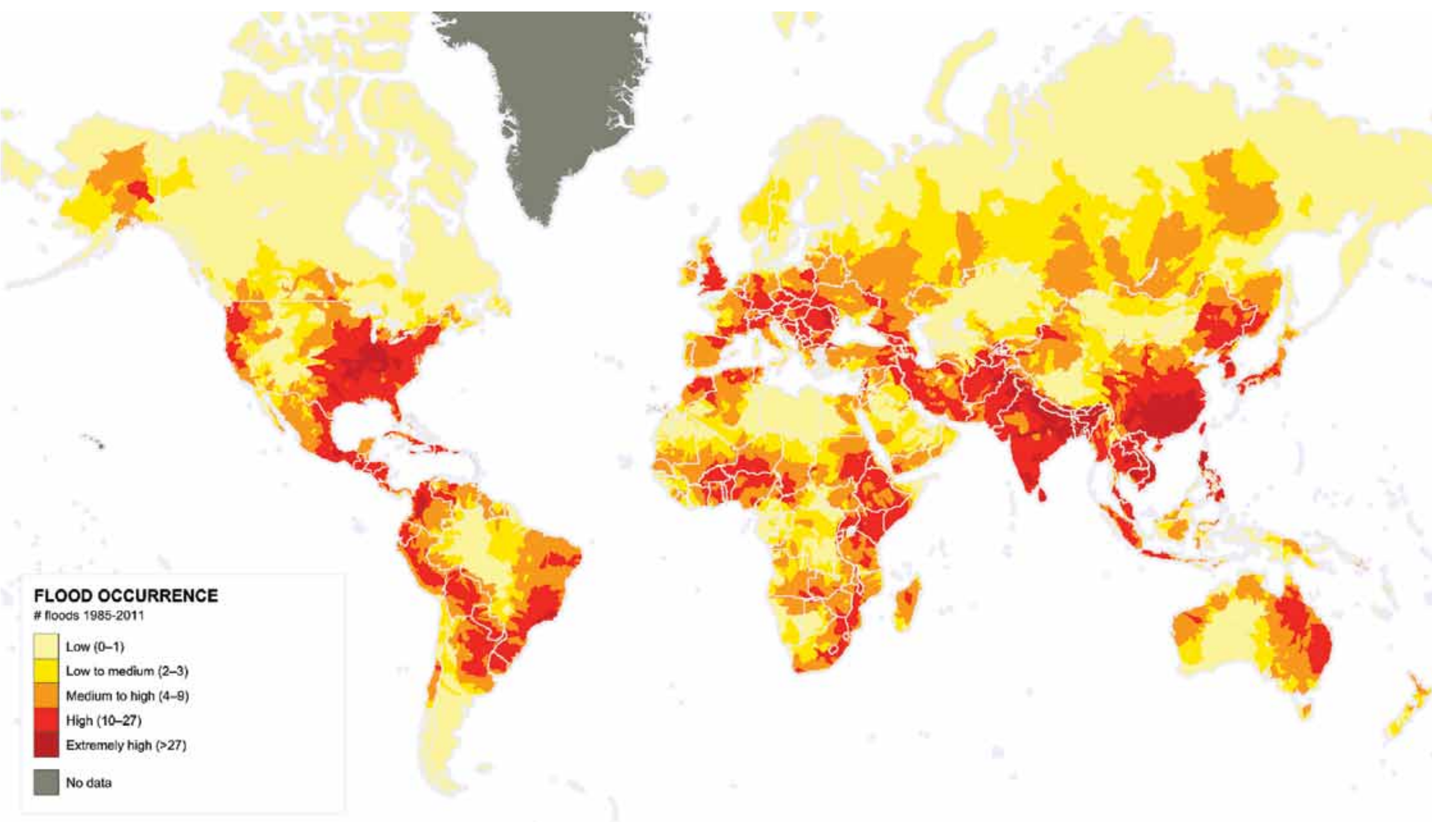
Description: *Flood occurrence* is the number of floods recorded from 1985 to 2011.

Calculation: Number of flood occurrences (1985-2011). Flood counts were calculated by intersecting hydrological units with estimated flood extent polygons.

Data Sources

VARIABLE	LARGE FLOOD EVENTS
Authors	G.R. Brakenridge, Dartmouth Flood Observatory, University of Colorado
Title	Global Active Archive of Large Flood Events
Time covered in analysis	1985 – October 2011
URL	http://floodobservatory.colorado.edu/Archives/index.html
Date accessed	October 15, 2011
Resolution	Flood extent polygons (multiple scales)
Comments	The Global Active Archive of Major Flood Events aggregates flood events from news, governmental, instrumental, and remote sensing sources and estimates the extent of flooding based on reports of affected regions.

Flood Occurrence



DROUGHT SEVERITY

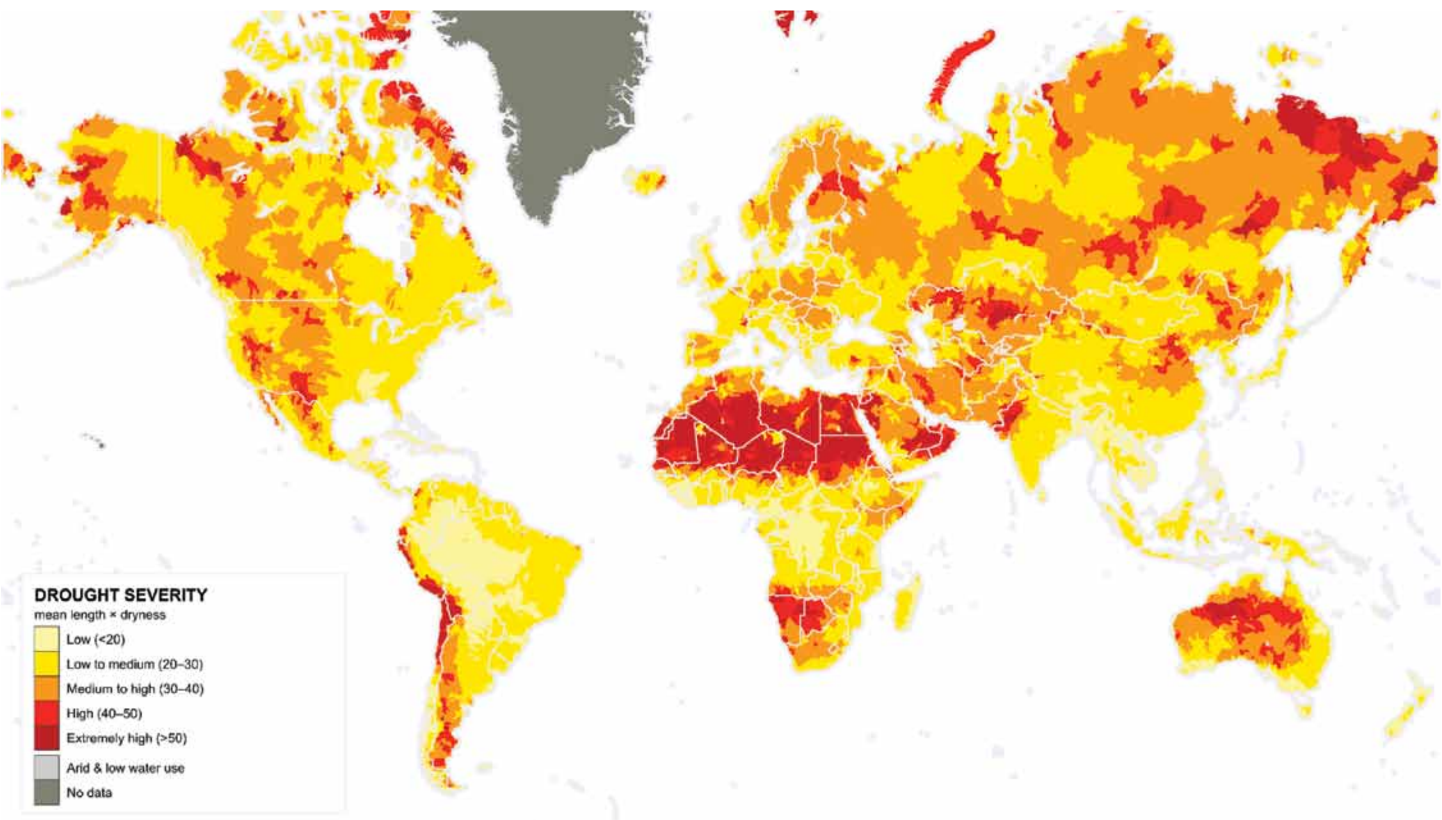
Description: *Drought severity* measures the average length of droughts times the dryness of the droughts from 1901 to 2008.

Calculation: Drought severity is the mean of the lengths times the dryness of all droughts occurring in an area. Drought is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in months, and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Drought data is resampled from original raster form into hydrological catchments.

Data Sources

VARIABLE	DROUGHT SEVERITY
Authors	J. Sheffield and E.F. Wood
Title	Projected Changes in Drought Occurrence under Future Global Warming from Multi-Model, Multi-Scenario, IPCC AR4 Simulations
Year of publication	2007
Time covered in analysis	1901–2008
URL	http://ruby.fgcu.edu/courses/twimberley/EnviroPhilo/Drought.pdf
Resolution	1 degree raster
Comments	Sheffield and Wood's drought dataset combines a suite of global observation-based datasets with the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP-NCAR) reanalysis, and creates a global drought event occurrence dataset with a spatial resolution of 1 degree.

Drought Severity



UPSTREAM STORAGE

Description: *Upstream storage* measures the water storage capacity available upstream of a location relative to the total water supply at that location. Higher values indicate areas more capable of buffering variations in water supply (i.e. droughts and floods) because they have more water storage capacity upstream.

Calculation: Upstream storage capacity divided by the mean of total blue water (1950–2008).

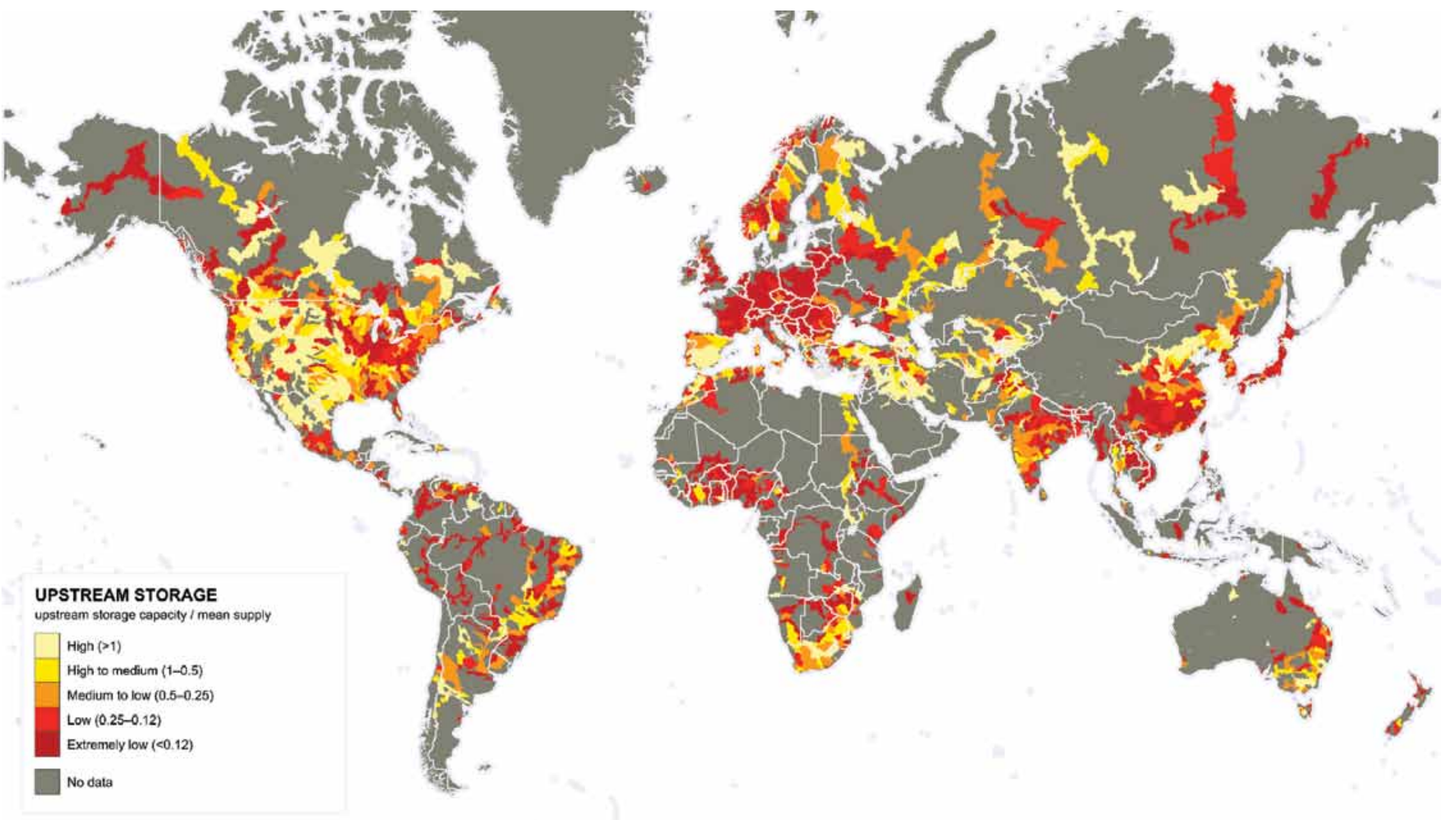
Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Data Sources

VARIABLE	MAJOR DAMS AND RESERVOIRS
Authors	B. Lehner, C. R-Liermann, C. Revenga, C. Vörösmarty, B. Fekete, P. Crouzet, P. Döll, et al.
Title	Global Reservoir and Dam (GRanD) Database Version 1.1
Year of publication	2011
Time covered in analysis	2010
URL	http://atlas.gwsp.org/index.php?option=com_content
Resolution	Dams (point)
Comments	GRanD database includes reservoirs with a storage capacity of more than 0.1 cubic km although many smaller reservoirs were included. The database includes approximately 6,862 dams and reservoirs around the world.

Upstream Storage



GROUNDWATER STRESS

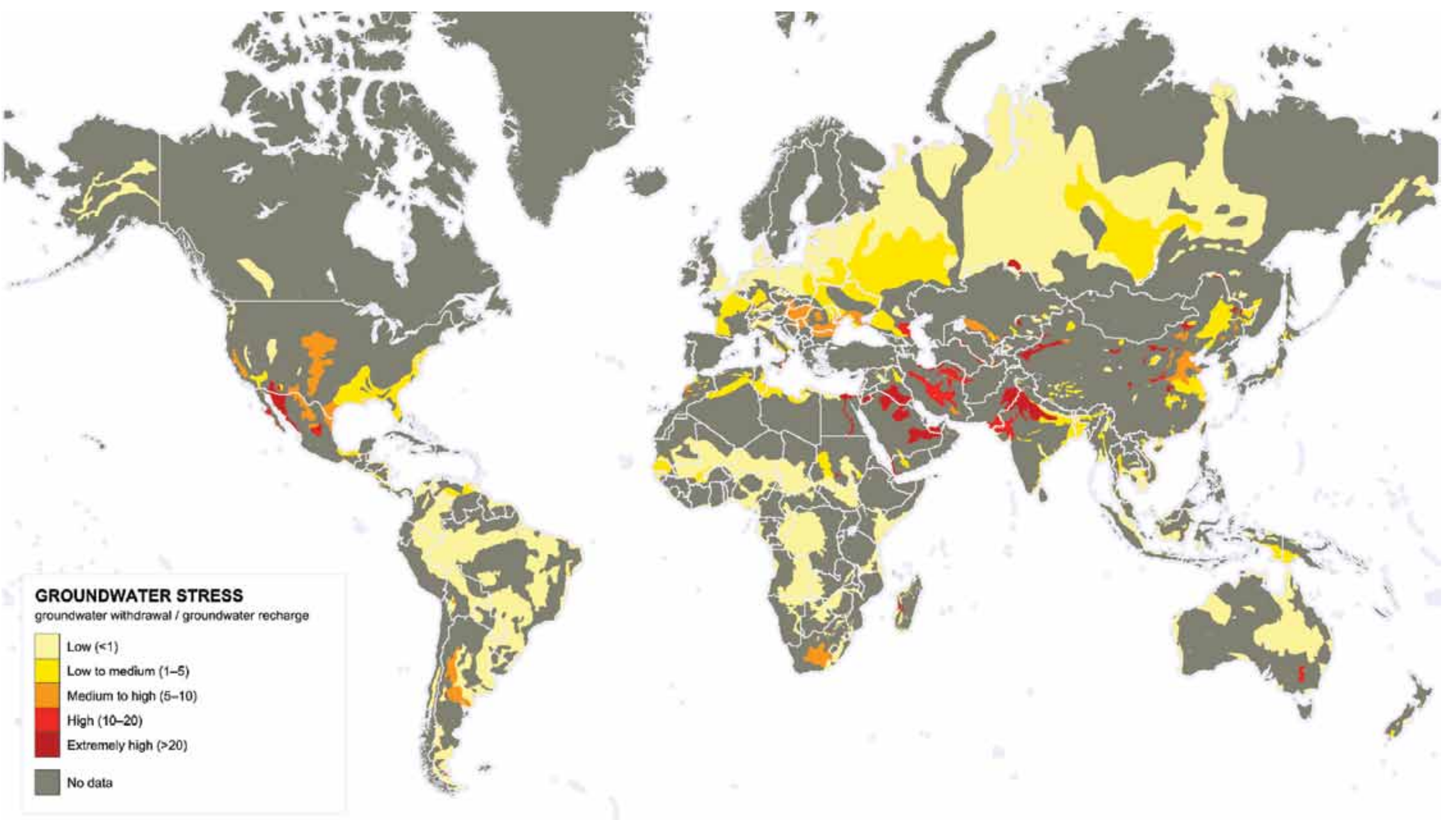
Description: *Groundwater stress* measures the ratio of groundwater withdrawal relative to its recharge rate over a given aquifer. Values above one indicate where unsustainable groundwater consumption could affect groundwater availability and groundwater-dependent ecosystems.

Calculation: Groundwater footprint divided by the aquifer area. Groundwater footprint is defined as $A[C/(R-E)]$, where C, R, and E are respectively the area-averaged annual abstraction of groundwater, recharge rate, and the groundwater contribution to environmental stream flow. A is the areal extent of any region of interest where C, R, and E can be defined.

Data Sources

VARIABLE	GROUNDWATER FOOTPRINT
Authors	T. Gleeson, Y. Wada, M.F. Bierkens, and L.P. van Beek
Title	Water Balance of Global Aquifers Revealed by Groundwater Footprint
Year of publication	2012
Time covered in analysis	1958–2000
URL	http://www.nature.com/nature/journal/v488/n7410/full/nature11295.html
Resolution	Polygons

Groundwater Stress



RETURN FLOW RATIO

Description: *Return flow ratio* measures the percent of available water previously used and discharged upstream as wastewater. Higher values indicate higher dependence on treatment plants and potentially lower water quality in areas that lack sufficient treatment infrastructure and policies. Arid areas with low water use are shown in gray, and scored as low stress when calculating aggregated scores.

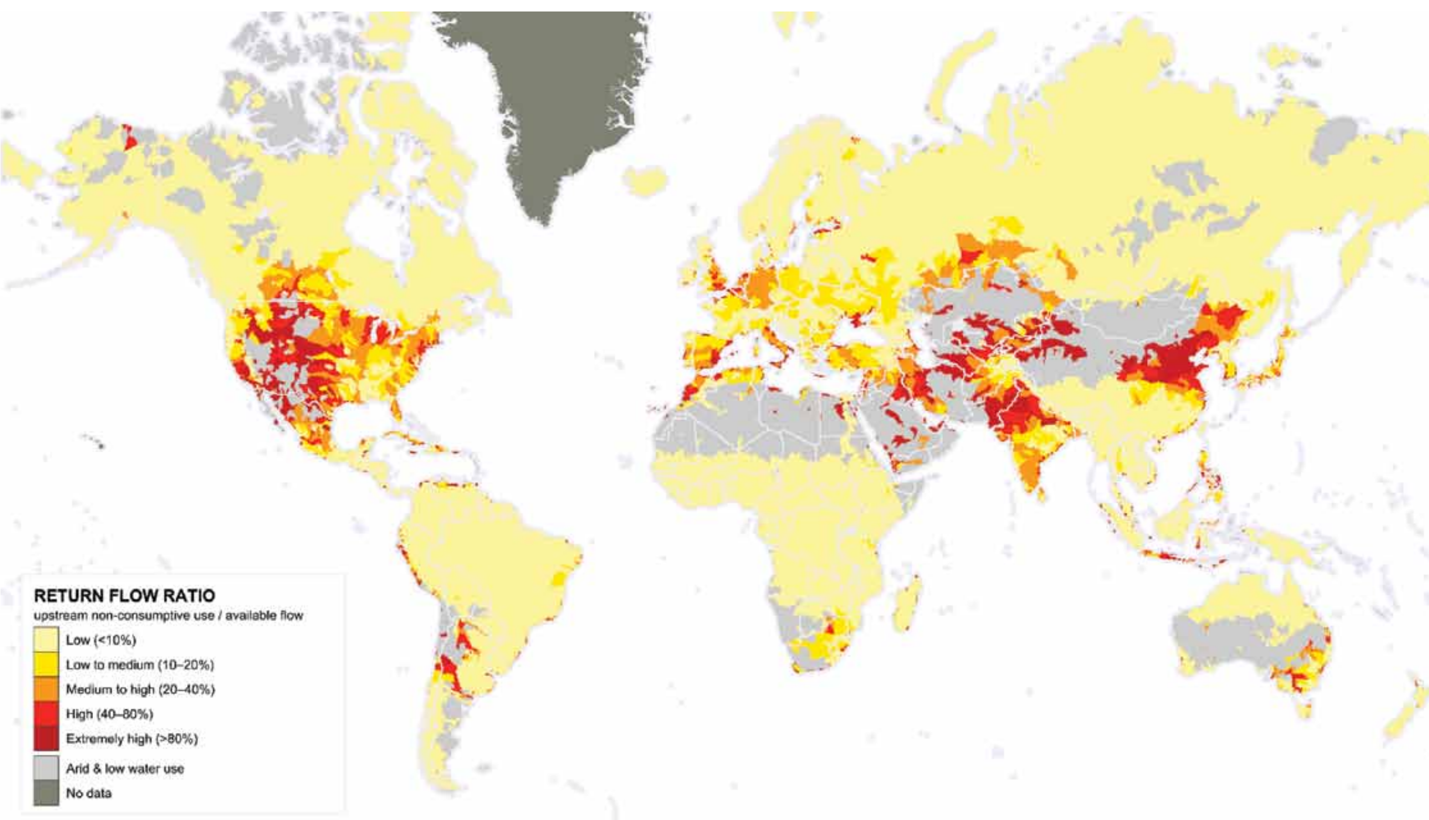
Calculation: Upstream non-consumptive use divided by the mean of available blue water (1950–2008). Areas with available blue water and accumulated upstream non-consumptive use less than 0.03 and 0.012 m/m2 respectively are coded as "arid and low water use".

Data Sources

VARIABLE	NON-CONSUMPTIVE USE
Comments	See Consumptive and Non-consumptive Use

VARIABLE	AVAILABLE BLUE WATER
Comments	See Available Blue Water

Return Flow Ratio



UPSTREAM PROTECTED LAND

Description: *Upstream protected land* measures the percentage of total water supply that originates from protected ecosystems. Modified land use can affect the health of freshwater ecosystems and have severe downstream impacts on both water quality and quantity.

Calculation: Percentage of total blue water that originates in protected areas. IUCN category V protected lands, as well as a large number of unclassified proposed lands, breeding centers, municipal parks, cultural and historic sites, and exclusively marine areas, are excluded.

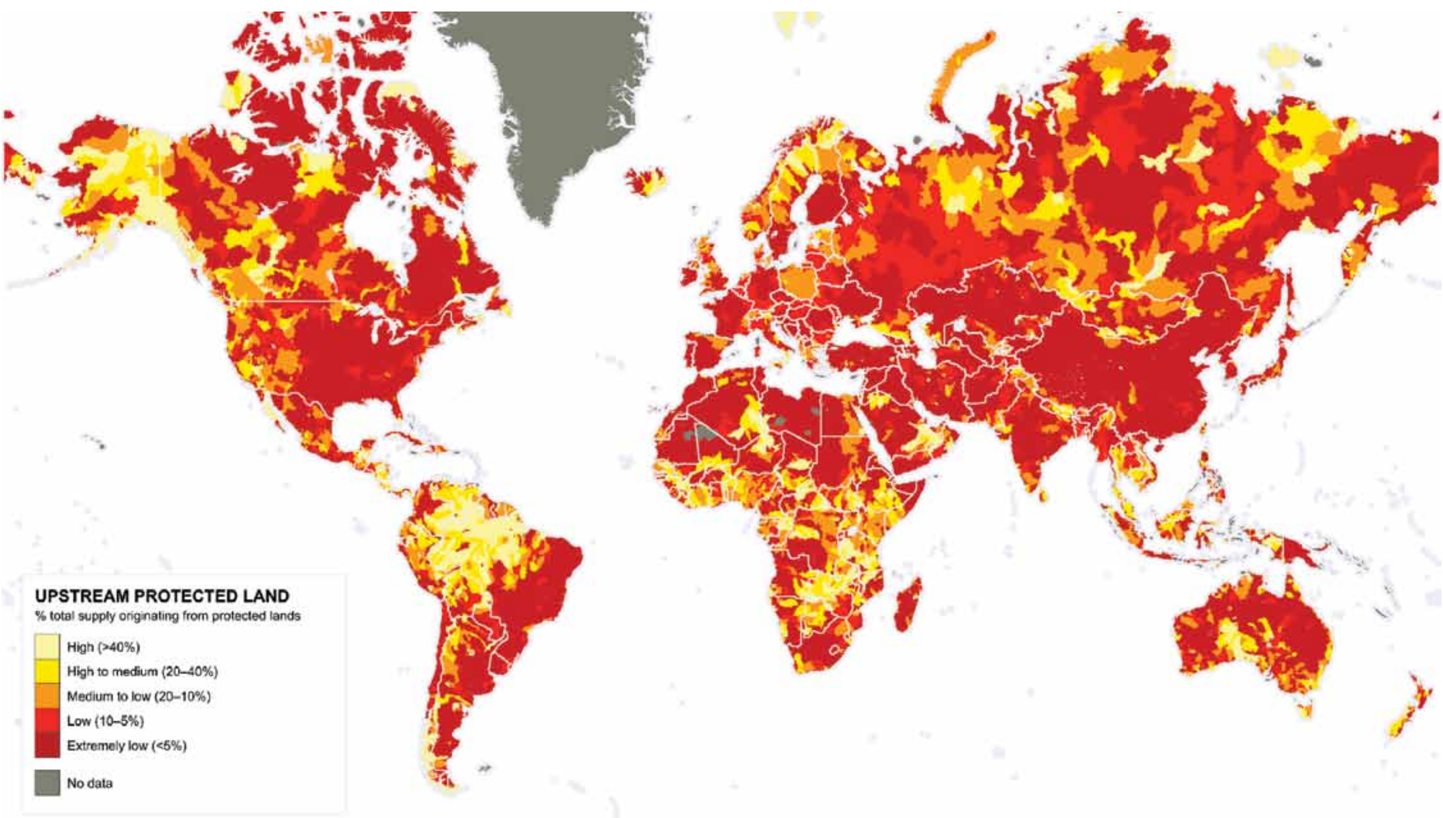
Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Data Sources

VARIABLE	PROTECTED AREAS
Authors	International Union for Conservation of Nature (IUCN) and United Nations Environment Programme World Conservation Monitoring Centre (UNEP–WCMC)
Title	The World Database on Protected Areas
URL	http://protectedplanet.net/
Date accessed	June 14, 2012
Resolution	Protected areas (multiple scales)

Upstream Protected Land



MEDIA COVERAGE

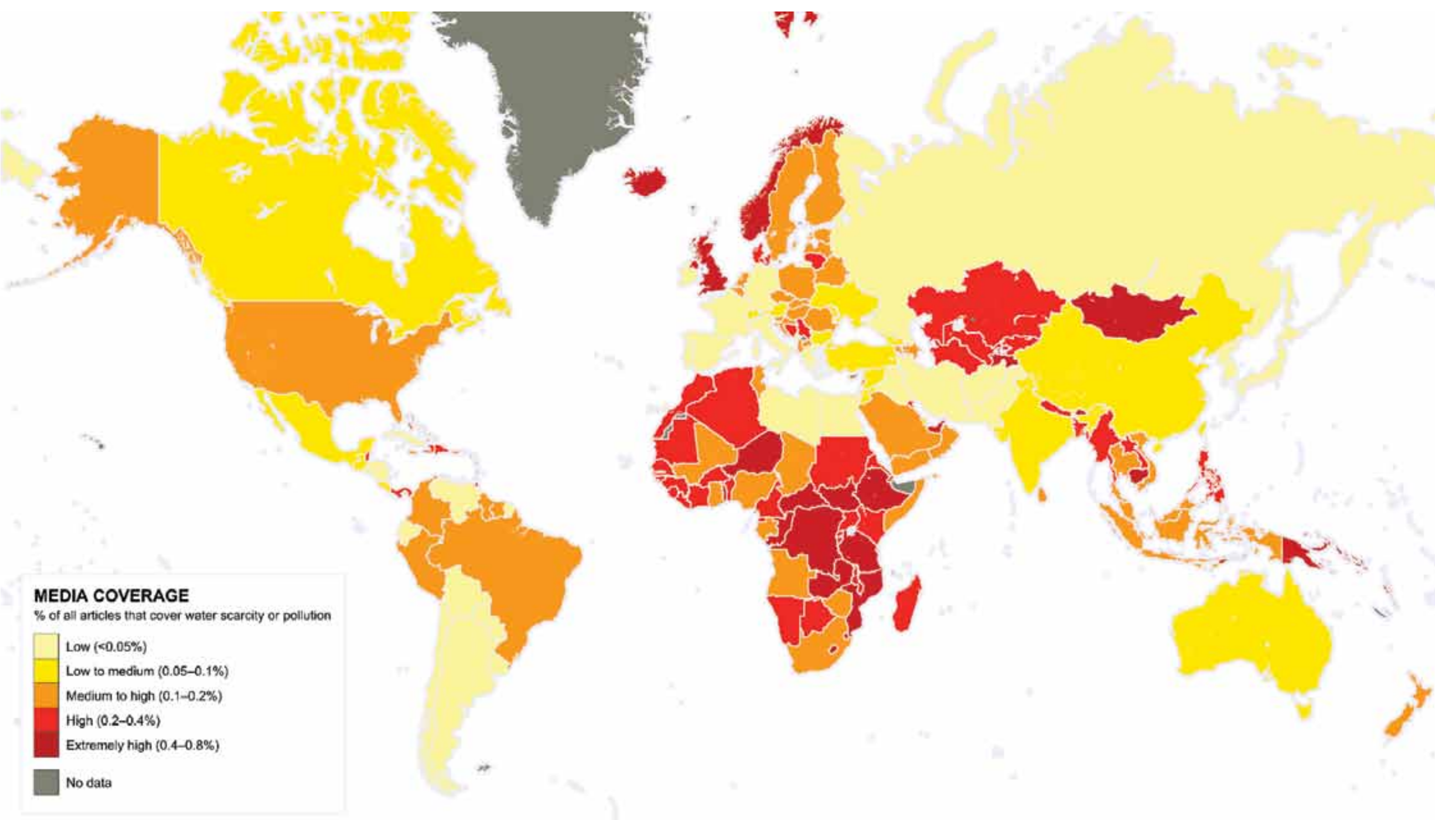
Description: *Media coverage* measures the percentage of all media articles in an area on water-related issues. Higher values indicate areas with higher public awareness about water issues, and consequently higher reputational risks to those not sustainably managing water.

Calculation: Percentage of all media articles on water scarcity and/or pollution. Google Archives was used to search a string of keywords including a river name, "water shortage" or "water pollution," and an administrative unit, e.g. "River+ water shortage + Country." The time frame was limited to the past 10 years from January 1, 2002 to December 31, 2011. For each country, the number of articles on water shortage and water pollution was summed and divided by the total number of articles on any topic found when searching for the administrative unit.

Data Sources

VARIABLE	MEDIA COVERAGE
Author	Google
Title	Google News
Time covered in analysis	2002–2012
URL	http://news.google.com/news/advanced_news_search?as_drrb=a
Date accessed	September 26, 2012
Resolution	Country
Comments	Media articles are limited to English articles.

Media Coverage



ACCESS TO WATER

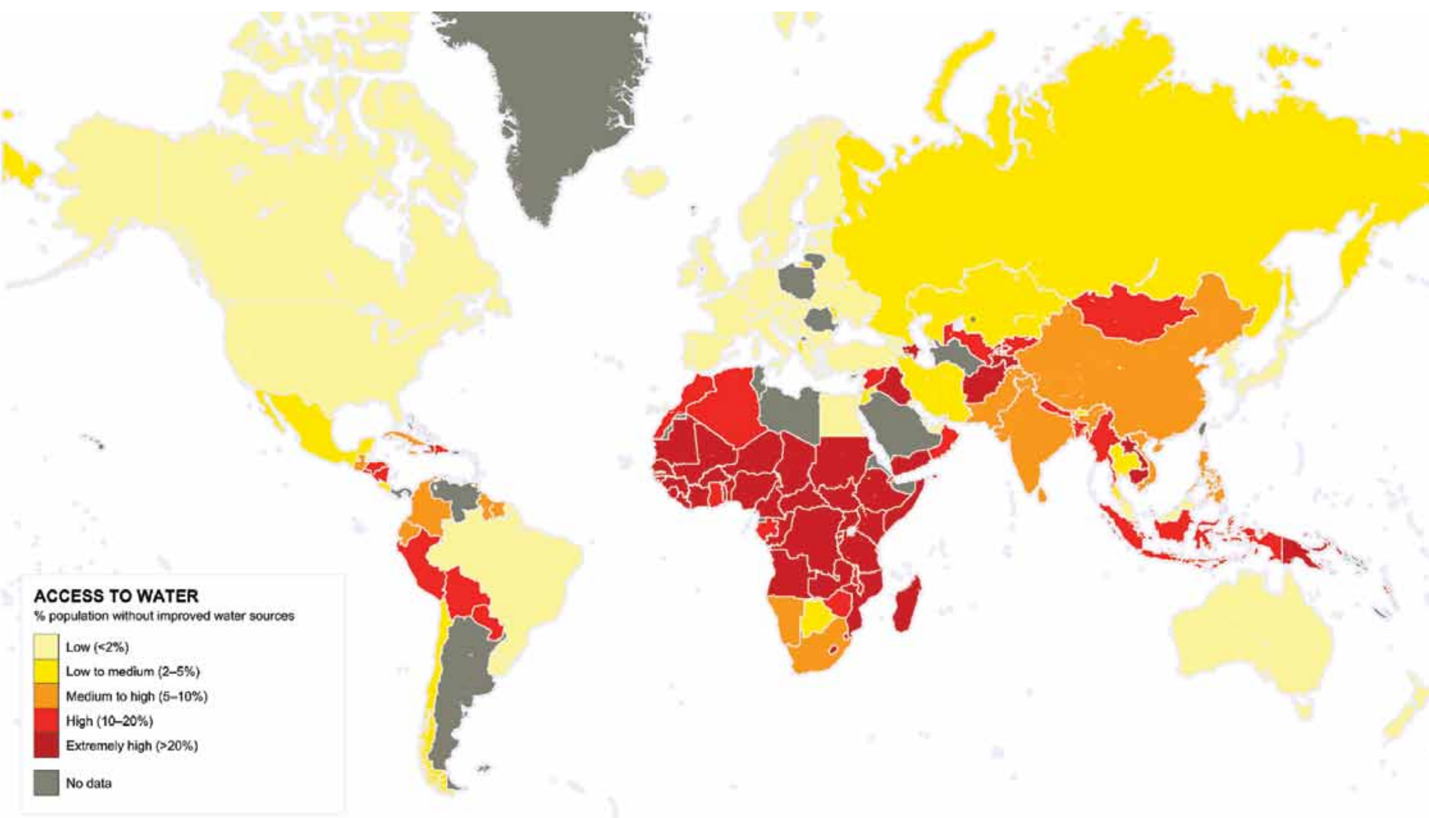
Description: *Access to water* measures the percentage of population without access to improved drinking water sources. Higher values indicate areas where people have less access to safe drinking water, and consequently higher reputational risks to those not using water in an equitable way.

Calculation: Percentage of population without access to improved drinking-water sources. An improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter.

Data Sources

VARIABLE	ACCESS TO WATER
Authors	World Health Organization (WHO) and the United Nations Children's Fund (UNICEF)
Title	WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation
Year of publication	2012
Time covered in analysis	2010
URL	http://www.wssinfo.org/
Resolution	Country

Access to Water



THREATENED AMPHIBIANS

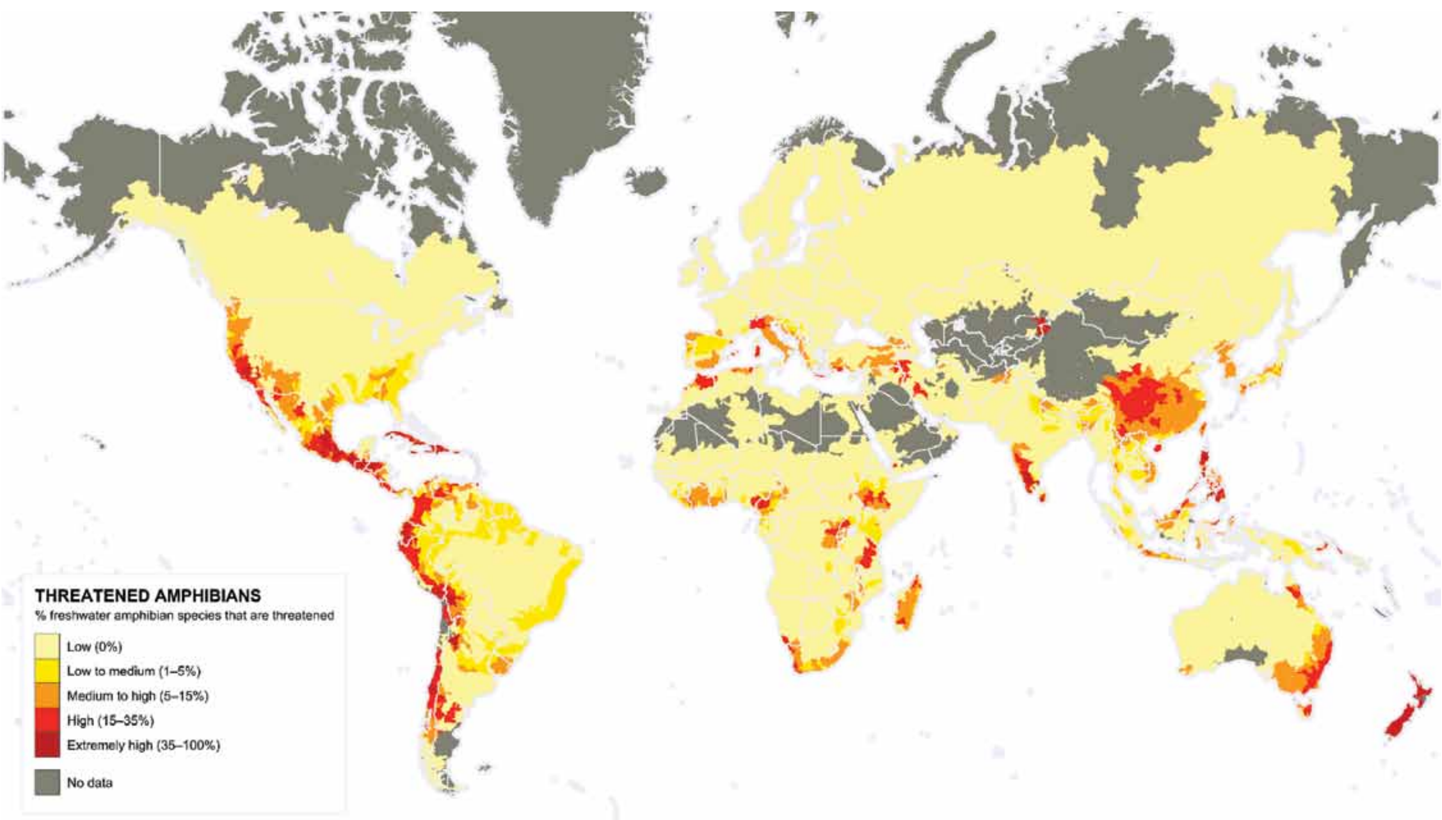
Description: *Threatened amphibians* measures the percentage of freshwater amphibian species classified by IUCN as threatened. Higher values indicate more fragile freshwater ecosystems and may be more likely to be subject to water withdrawal and discharge regulations.

Calculation: The percentage of amphibian species classified by IUCN as threatened in a particular area. For each catchment, the total number of threatened freshwater amphibian species was counted and divided by the total number of freshwater amphibian species whose ranges overlap the catchment. Catchments with fewer than two amphibian species were excluded.

Data Sources

VARIABLE	THREATENED AMPHIBIANS
Author	International Union for Conservation of Nature (IUCN)
Title	The IUCN Red List of Threatened Species
Year of publication	2010
Time covered in analysis	2010
URL	http://www.iucnredlist.org/technical-documents/spatial-data#amphibians
Resolution	Polygons
Comments	Freshwater amphibian species status database is joined to the known species range spatial data. Several name corrections were made in joining the data.

Threatened Amphibians



ENDNOTES

1. Paul Reig, Tien Shiao, and Francis Gassert. Aqueduct Water Risk Framework, WRI Working Paper, Washington DC: World Resources Institute, forthcoming.

2. Yuji Masutomi, Yusuke Inui, Kiyoshi Takahashi, and Yuzuru Matsuoka. "Development of Highly Accurate Global Polygonal Drainage Basin Data," Hydrological Processes 23: 572-84, DOI: 10.1002/hyp.7186, 2009.

3. I.A. Shiklomanov and John C. Rodda, eds. World Water Resources at the Beginning of the Twenty-First Century, International Hydrology Series, Cambridge University Press, 2004.

4. M. Flörke, E. Kynast, I. Bärlund, S. Eisner, F. Wimmer, J. Alcamo, "Domestic and Industrial Water Uses of the Past 60 Years as a Mirror of Socio-Economic Development: A Global Simulation Study," Global Environmental Change, in press, 2012.

5. National Aeronautics and Space Administration (NASA). Global Land Data Assimilation System Version 2 (GLDAS-2), Goddard Earth Sciences Data Information Services Center, 2012.

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- Cy Jones, World Resources Institute
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- Justin Sheffield, Princeton University
- Richard Vogel, Tufts University
- Yoshihide Wada, Utrecht University

ABOUT WRI

WRI focuses on the intersection of the environment and socio-economic development. We go beyond research to put ideas into action, working globally with governments, business, and civil society to build transformative solutions that protect the earth and improve people's lives.

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